

# **burleigh**

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**MODEL 6000ULN SERIES  
ULTRA LOW NOISE  
INCHWORM CONTROLLER**

**Operating  
Manual**



# **MODEL 6000 ULN SERIES ULTRA LOW NOISE INCHWORM CONTROLLER OPERATING MANUAL**

Operating Manual (Rev. G)  
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## TABLE OF CONTENTS

|                                                |            |
|------------------------------------------------|------------|
| <b>1. INTRODUCTION.....</b>                    | <b>1-1</b> |
| 1.1 Safety.....                                | 1-1        |
| 1.2 Burleigh Quality Control .....             | 1-2        |
| <b>2. SYSTEM OVERVIEW.....</b>                 | <b>2-1</b> |
| 2.1 System Configurations .....                | 2-1        |
| 2.2 Computer Interfacing.....                  | 2-2        |
| 2.2.1 Model 671-X LabVIEW.....                 | 2-2        |
| 2.2.2 Model 672-X RS-232.....                  | 2-2        |
| 2.2.3 Computer Interfacing Summary Table ..... | 2-3        |
| <b>3. INSTALLATION.....</b>                    | <b>3-1</b> |
| 3.1 Initial Test .....                         | 3-1        |
| 3.2 Location .....                             | 3-1        |
| 3.3 Connecting Inchworm Motors .....           | 3-1        |
| 3.4 Connecting The Model 6003 Joystick .....   | 3-2        |
| 3.5 Connecting The Model 6005 Handset .....    | 3-2        |
| 3.6 Interfacing To Encoders.....               | 3-2        |
| 3.6.1 Analog Interface .....                   | 3-2        |
| 3.6.2 Differential TTL Interface .....         | 3-2        |
| 3.6.3 Single-Ended TTL Interface.....          | 3-3        |
| 3.7 Selecting Display Resolution .....         | 3-3        |
| 3.8 Line Voltage Selection .....               | 3-3        |
| <b>4. OPERATION .....</b>                      | <b>4-1</b> |
| 4.1 Front Panel (6200 ULN Only) .....          | 4-1        |
| 4.1.1 Setting Travel.....                      | 4-1        |

|                   |                                                         |            |
|-------------------|---------------------------------------------------------|------------|
| 4.1.2             | Loop.....                                               | 4-2        |
| 4.1.3             | Setting Maintenance Speed (MSPEED) and DWELL .....      | 4-2        |
| 4.2               | Model 6003 Joystick (All Models) .....                  | 4-3        |
| 4.3               | Model 6005 Handset.....                                 | 4-4        |
| <b>5.</b>         | <b>INTERFACING .....</b>                                | <b>5-1</b> |
| 5.1               | Manual Port Open Loop Interface (6000 ULN) .....        | 5-1        |
| 5.1.1             | Manual Port Pin Descriptions (Open Loop).....           | 5-1        |
| 5.1.2             | Manual Port Open Loop Pin Functions.....                | 5-2        |
| 5.2               | Manual Port Closed Loop Interface (6200ULN).....        | 5-5        |
| 5.2.1             | Manual Port Pin Descriptions (Closed Loop).....         | 5-5        |
| 5.2.2             | Manual Port Closed Loop Pin Functions .....             | 5-6        |
| 5.3               | Auxiliary Port Closed Loop Interfacing (6200 ULN) ..... | 5-8        |
| 5.3.1             | Auxiliary Port Pin Descriptions .....                   | 5-9        |
| 5.3.2             | Auxiliary Port Pin Functions .....                      | 5-10       |
| 5.4               | Operation .....                                         | 5-11       |
| 5.4.1             | Hardware and Software Protocol Definitions .....        | 5-12       |
| <b>6.</b>         | <b>TROUBLESHOOTING .....</b>                            | <b>6-1</b> |
| 6.1               | General Troubleshooting.....                            | 6-1        |
| 6.2               | General High Voltage Circuit Evaluation .....           | 6-1        |
| <b>7.</b>         | <b>WARRANTY.....</b>                                    | <b>7-1</b> |
| <b>APPENDIX A</b> | <b>SPECIFICATIONS.....</b>                              | <b>A-1</b> |
| <b>APPENDIX B</b> | <b>WAVEFORMS .....</b>                                  | <b>B-1</b> |
| <b>APPENDIX C</b> | <b>CONNECTOR PINOUTS.....</b>                           | <b>C-1</b> |
| <b>APPENDIX D</b> | <b>HARDWARE CONFIGURATIONS .....</b>                    | <b>D-1</b> |

## 1. INTRODUCTION

Burleigh Instruments, Inc. thanks you for choosing our Model 6000 ULN Series Ultra Low Noise Inchworm Controller. Its design has been optimized for the operation of Burleigh's IW-700 Series, LTS/LTO Series, TSE Series, and Ultra High Vacuum Inchworm Motors in noise sensitive applications.

This manual covers all of the controllers and accessories shown in Table 1. The Inchworm Motors are covered in separate manuals. Appendix A is a specification summary for this controller. Appendix B shows the high voltage waveforms generated by these controllers.

Burleigh Instruments introduced Inchworm Motor Systems in the early 1970's. These unique piezoelectric devices produce ultra-high resolution linear motion with no backlash or leadscrew errors. They are indispensable in a wide range of applications including fiber optic alignment, disk drive media verification, cellular recording, and scanning probe microscopy.

Please take time to familiarize yourself with the 6000 ULN System by reading this manual and understanding each of your system's components.

### 1.1 Safety

Failure to correctly install and operate the system may result in damage to the controller and/or motors and can create hazards to personnel.

**CAUTION:** The 6000 ULN Series Controller is a high voltage and current device. Contact with internal high voltage components can be extremely dangerous. NEVER service the controller, cabling, or other connected components with the line power connected.

The 6000 ULN Series Controller will maintain high voltage levels for some time after the power is removed. Always wait at least 5 minutes after disconnecting power before removing any covers, circuit boards, cables, etc. for service.

Never connect or disconnect ANY cables from any 6000 ULN Series Controller while the power is on. This includes the Inchworm Motor cables, encoder cables, communication cables, etc. Failure to observe this caution may result in damage to the controller and/or associated computer systems. Burleigh Instruments assumes no liability for this type of damage which will additionally void the product warranty.

During normal operation certain internal components of the 6000 ULN Series Controllers may become hot. Use care during service operations to avoid burns.

## 1.2 Burleigh Quality Control

Your Model 6000 ULN Series Controller has been inspected, tested, calibrated, and burned-in at elevated temperatures before shipment. It is conservatively designed and should provide years of trouble free operation. In the event of any problems please contact Burleigh for instructions. Our Customer Service Department is always ready to help with advice, parts, and repair services.

## 2. SYSTEM OVERVIEW

### 2.1 System Configurations

There are three general configurations of 6000 ULN Series Inchworm Motor Controllers: Open Loop, Closed Loop, and OEM. They differ mainly in how they interface with control devices. (See Table 1).

The first type of system is the **Open Loop System**, Model 6000 ULN. This system is interfaced via the "Manual Port". Inputs to this port are TTL level signals which actuate forward and reverse Inchworm Motor operations. This port directly interfaces with the Model 6003 Joystick and the Model 6005 Handset for manual control, or the Model 671-1 PC Interface for computer control. It should be noted that use of this PC Interface in this configuration provides only unidirectional open loop position commands control of the Inchworm (see Section 5.1). Also note that all "clock signals" controlling motor speed are generated externally for all 6000 ULN Series Controllers.

The second type of system is the **Closed Loop System**. Model 6200 ULN accepts feedback from position encoding devices attached to the Inchworm Motor or stage. These controllers permit taking steps of known length and the maintenance of position under varying load. The front panel buttons and display allow setting and monitoring of various parameters. This model allows two levels of interfacing - one being a unidirectional port offering basic control commands and a more sophisticated port which allows bi-directional data transfer. An external control device can have greater control over the movements of the Inchworm Motor. In addition to receiving position information from the encoder, the port permits monitoring of limit switches, Inchworm Motor status, jumper positions, and a number of other useful parameters.

Model 6200 ULN can be operated via signals provided from the Model 671-2 PC Interface, which is easily installed in an IBM-PC or compatible computer. This provides high level language control allowing the development of sophisticated motion control programs. Note that communication is performed over a Burleigh specified bus. RS-232 communication is available with the 6000 ULN family of controllers via the Model 672-X Interface.

The third and final configuration of the 6000 ULN Series Controller is the OEM module form. The power supply and all cards are available separately for installation in OEM equipment. Many different configurations are possible. Contact Burleigh for more details.

## 2.2 Computer Interfacing

Three Computer interfaces are available for 6000/ULN Open and Closed Loop Interfacing. The XXX-1 interfaces specify Open Loop while the XXX-2 specify Closed Loop. Interface selection depends on your specific need and/or equipment available. Also note that the Open Loop Interface supports up to 3 axes control while the Closed Loop Interface supports up to 9 axes.

### 2.2.1 Model 671-X LabVIEW

The Model 671-X interface is intended for direct Host PC to 6000 Controller interfacing, running under Windows 95, and comes with a PC ISA Bus Interface Card, LabVIEW drivers, a .DLL (Dynamic Link Library), and sample/application demos and source code for Visual Basic 5.0 and Visual C++ 5.0 (using MFC).

### 2.2.2 Model 672-X RS-232

The Model 672-X is intended for control via an RS-232C interface. This interface will work with virtually any Host computer which supports the RS-232C protocol. The interface consists of a Slave PC which contains an Interface Card and control software. Also included in the package is a sample/test application program to help get you up and running more quickly.

## 2.2.4 Computer Interfacing Summary Table

| MODEL #          | DESCRIPTION | OPTIONS                                                                                                                                                                                                                                                                                                                                                          |
|------------------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6000 ULN         | Open Loop   | <ul style="list-style-type: none"> <li>• 100, 118, or 236 Volts</li> <li>• 1, 2, or 3 axis</li> <li>• Model 6005 Handset, or Model 6003 Joystick, or Model 67X-1 PC Interface (unidirectional communication only) *</li> <li>• Special higher mechanical resolution modification</li> </ul>                                                                      |
| 6200 ULN         | Closed Loop | <ul style="list-style-type: none"> <li>• 100, 118, or 236 Volts</li> <li>• 1, 2, or 3 axis</li> <li>• Model 6005 Handset, or Model 6003 Joystick **</li> <li>• 1, 0.5, 0.2, 0.1, 0.05, 0.02, and 0.01µm resolution</li> <li>• Model 67X-2 PC Interface (bi-directional communication) **</li> <li>• Special higher mechanical resolution modification</li> </ul> |
| OEM Applications |             | * Consult factory                                                                                                                                                                                                                                                                                                                                                |

Table 1

\* With the Open Loop Interface, the “Manual Port” connects to either the Handset, Joystick, or the 67X-1 Interface - meaning they can not be used simultaneously.

\*\* With the Closed Loop Interface, the Handset (Joystick) must be turned “OFF” for proper operation.



### 3. INSTALLATION

#### 3.1 Initial Test

**IMPORTANT:** Before plugging in the line cord confirm that the voltage selector on the rear panel matches the available line voltage. Incorrect setting can cause permanent damage to the system.

DO NOT connect an Inchworm Motor to the controller until you have read and understood the Installation Section of this manual. This initial test is performed with nothing but the line cord connected to the controller.

After connecting the line cord, turn the instrument on using the toggle switch located on the rear panel - this is the rocker switch on the lower left side of the rear panel when viewed from the rear. The POWER and HV LED's on the front panel should be illuminated.

Should your instrument fail this initial check please contact Burleigh Instruments, Inc. or your local representative for further instructions.

**CAUTION:** Never attach an Inchworm motor to a controller with the power switched on. Permanent damage may occur to both systems.

Before switching on the controller be sure that the proper line voltage selection has been made and that the proper fuse is installed.

#### 3.2 Location

The Model 6000 ULN Series Inchworm Controller should be located in a convenient location.

1. Be sure that there is sufficient room around the chassis for proper cooling and that the vents are not blocked.
2. If the unit is to be operated with the 6005 Handset or 6003 Joystick, note that the cables for those devices are 6 feet in length. Locate the controller, experiment, and operator positions to permit adequate access to all components.
3. Inchworm Motors are supplied with 6 foot long cables. If the experiment requires that motors be operated at greater distances from the controller a Model 7011 Motor Extension Cable (and Model 7007 Extension Cable for Closed Loop Systems) must be used. See the Burleigh Products Catalog for available lengths up to 15 meters.

#### 3.3 Connecting Inchworm Motors

Turn off the power switch located on the rear panel of the controller. Push the connector on the Inchworm Motor cable onto one of the connectors on the rear of the controller marked DEVICE. Be sure to push the connectors fully together so that the latches on the connectors lock.

For Closed Loop Systems push the connector on the Encoder cable onto the rear panel chassis connector marked ENCODER. This connector is located next to the DEVICE connector and under the label indicating an axis number.

### 3.4 Connecting The Model 6003 Joystick

Turn off power to the controller. Plug one end of the cable into the controller's rear panel MANUAL PORT connector and secure it using the two capture screws. Plug the other end of the cable into the connector located at the rear of the joystick and secure it using the captive screws.

### 3.5 Connecting The Model 6005 Handset

Turn off the power to the controller. Plug the connector on the handset cable into the controller's rear panel MANUAL PORT connector. Secure the connector with the two capture screws located on the connector.

### 3.6 Interfacing To Encoders

The 6200 ULN Controller can interface with three different types of quadrature encoder signals, namely Analog, Differential TTL, and Single-Ended TTL. Quadrature Analog is standard with the other interfaces available from the factory or as user installed conversion kits.

**NOTE:** The rear panel connectors are labeled with the encoder type but are otherwise identical. It is important that you use the proper encoder/interface combinations.

#### 3.6.1 Analog Interface

All Burleigh 0.5 micron encoders use this interface. The interface is identified by observing a piggyback circuit board installed on the Counter/CPU circuit board. In addition the back panel of the controller will have an ANALOG label indicating the type of interface. Connection is made by disconnecting the power and then plugging the encoder's 9-pin connector into the encoder connector on the controller.

Encoders are supplied with 6 foot long cables. If the encoders need to be farther than this distance from the controller, then see the Burleigh Products Catalog for lengths up to 15 meters.

#### 3.6.2 Differential TTL Interface

This interface is used with the 0.05 micron Heidenhain Encoder Systems in which the Heidenhain EXE 650B Encoder Box plugs directly into this interface. The interface is identified by observing two DS8820A integrated circuits installed in sockets U18 and U19 on the Counter/CPU circuit board. The rear panel of the controller is labeled "DIF/QUAD" to indicate the presence of this interface.

Connection is made to the Heidenhain EXE 650B Encoder Box by simply plugging the cable from the Heidenhain into the ENCODER connector on the controller. This interface may also be used with other encoders which supply differential quadrature signals.

### 3.6.3 Single-Ended TTL Interface

This type of interface is used with ACCURITE 1 micron encoders. This interface is present if the sockets U18 and U19, on the Counter/CPU circuit board, contain component headers labeled 04077-3. In addition the rear panel of the controller will bear a SINGLE/QUAD label. Connection is made by removing power and then plugging the encoder cable into the ENCODER connector on the controller.

## 3.7 Selecting Display Resolution

If a Closed Loop Controller is equipped with a Digital Display, the resolution jumpers of the Counter/CPU circuit board must be configured to match the resolution on the encoder being used. The jumpers may be set for encoders with 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, and 1.0 micron resolution. See Appendix D for jumper locations and settings.

## 3.8 Line Voltage Selection

The Model 6000 ULN Series Controller can be configured for operation at the standard outlet voltages of 100/120/220/240 VAC at 47-63 Hz.

Your controller has been setup and tested with your country's voltage power settings. Each of the AC power selections for the controller can be configured by opening the access cover of the line filter on the rear panel of the electronic controller. The current voltage selection is displayed in a window in the access cover. If the wrong voltage is displayed in this window, open the access cover and reset the voltage.

With the cover open, you will see at the top of the line filter, a voltage selection drum. With the cover open, you will see at the top of the line filter, a voltage selection drum. Remove this drum and rotate the drum until the proper voltage selection appears. Replace the drum in the filter (Do not attempt to rotate the drum while still mounted in the line filter. It can damage the internal switch contacts.) Remove the fuse(s) located directly below the voltage selection drum and replace with the appropriately rated fuse(s). Newer controllers use one 3.0 Amp Slow Blow fuse (100 Volt versions use a 4.0 Amp fuse). Table 3.1 lists the available voltages and appropriate fuses for older models of the controller.

Close the access cover, the appropriate voltage should now appear in the line filter's window.

| Volts               | Frequency | Fuse Rating        |
|---------------------|-----------|--------------------|
| 100 VAC, $\pm 10\%$ | 47-63 Hz. | 1.5 Amp Slow Blow  |
| 120 VAC, $\pm 10\%$ | 47-63 Hz. | 1.0 Amp Slow Blow  |
| 220 VAC, $\pm 10\%$ | 47-63 Hz. | 0.75 Amp Slow Blow |
| 240 VAC, $\pm 10\%$ | 47-63 Hz. | 0.75 Amp Slow Blow |

**Table 3.1. . The available voltages and the appropriate fuses.**



## 4. OPERATION

Model 6000 ULN Series Controllers require an external clock for sequencing the Inchworm Motor drive signals. To operate the controller, the motor's clock signals must be supplied by an external source such as a 6005 Handset, a 6003 Joystick, or user supplied TTL signals.

**NOTE:** Open Loop (6000 ULN) Controllers may only be operated via joystick, handset, 67X-1 Interface, or user supplied TTL signals. For more information please refer to Sections 4.2, 4.3 and 5.

### 4.1 Front Panel (6200 ULN Only)

The front panel switches and displays of closed loop controllers permit setting and/or reading a number of useful parameters.

#### 4.1.1 Setting Travel

TRAVEL is the distance in user selected units of  $\mu\text{m}$ , MM or IN that an Inchworm motor will move when a STEP is taken. It is set using the front panel switches as follows.

1. Repeatedly press the DISPLAY switch until the TRAVEL light is illuminated. The controller is now in the input mode and the other switches have their alternate functions (as labeled under each button).
2. Pressing the up arrow switch will cause the right most digit to begin automatically incrementing in value. When the digit increments past '9' the digit to its left will increment by one while the first digit continues incrementing. Pressing the down arrow switch will cause the digit that is currently incrementing to begin decrementing.
3. The display can be cleared at any time by pressing the CLEAR switch.
4. To return the system to operating mode, press the DISPLAY switch until the indicators are extinguished and motor position is displayed.

**NOTE:** The process just described is only suitable for setting relatively small values of TRAVEL because the rate of automatic incrementing is slow. The following method is suggested for setting large TRAVEL values.

1. Repeatedly press the DISPLAY switch until the TRAVEL light is illuminated. The controller is now in the input mode and the other switches have their alternate functions.
2. Press the CLEAR switch to blank the display.
3. Repeatedly press the up arrow switch until the left most digit, your desired TRAVEL setting, is illuminated and begins automatic incrementing.

**NOTE:** It is normal for digits to the right of the selected digit to be filled with ones or other numbers if the up arrow is pressed rapidly.

4. Press the CLEAR switch to clear the display. Note that the selected digit is still auto incrementing and that the numbers to the right of it are all zero.
5. When the selected digit is at the desired value, press the STOP switch.

**NOTE:** If the selected digit proceeds beyond the desired number, before pressing the STOP switch pressing the down arrow switch will cause that digit to begin decrementing thus providing a second chance. Once again be sure to press the STOP switch when the desired value is displayed.

#### 4.1.2 Loop

If you wish to set digits to the right of the digit already set, proceed as follows:

1. Repeatedly press the up arrow switch until the left most digit remaining to be input is illuminated and begins automatic incrementing.
2. When the selected digit is at the desired value press, the STOP switch.

**NOTE:** If the selected digit proceeds beyond the desired number, before pressing the STOP switch pressing the down arrow switch will cause that digit to begin decrementing thus providing a second chance. Once again be sure to press the STOP switch when the desired value is displayed.

3. When the desired number is displayed in full press the DISPLAY switch until the MSPEED, TRAVEL, and DWELL lights are off.
4. Repeat Steps 1, 2, and 3 until all digits are set.

#### 4.1.3 Setting Maintenance Speed (MSPEED) and DWELL

Large inertial loads may prohibit the Inchworm Motor from settling to its desired position (i.e. "dither"). This dithering may interfere with your experiment and can be minimized by adjusting MSPEED and DWELL. When MSPEED is reduced the speed of the Inchworm Motor to make corrections is slowed thus minimizing overshoot. If the load tends to 'ring', setting the DWELL time to a larger value will permit the system to settle before the next correction is made.

**NOTE:** MSPEED and DWELL are factory preset to values suitable for most applications. For most applications it should not be necessary to change their values.

**CAUTION:** MSPEED and DWELL are adjusted by turning potentiometers inside the controller while the power is on. High voltages are present inside the controller when the adjustments are being made so care must be taken in keeping fingers, tools, and jewelry away from the controller except as indicated in these instructions.

**Do not work alone. High voltages are present whenever power is applied in the controller.**

To adjust the MSPEED and DWELL values proceed as follows:

1. Turn off power to the controller.
2. Remove the screws securing the top cover of the controller and lift off the cover.
3. Locate the MSPEED (RV1) and DWELL (RV2) potentiometers on the circuit boards. See Appendix D.
4. Turn on the power to the controller. Remember that HIGH VOLTAGE is present at this time.

**NOTE:** The following is written for adjusting MSPEED. In order to set DWELL proceed in exactly the same manner substituting "DWELL" for "MSPEED" in all that follows.

5. Repeatedly press the DISPLAY switch until the MSPEED indicator is illuminated and its value is displayed.
6. Slowly rotate the MSPEED potentiometer until the desired value is displayed.

**CAUTION:** In order to avoid electrical shock hazard be sure to use an electrically insulated screw driver or a special potentiometer adjusting tool.

7. Turn off power to the controller and replace the cover securing it with the screws.

## 4.2 Model 6003 Joystick (All Models)

The joystick permits independent or simultaneous operation of up to 3 Inchworm Motors with a suitably configured Model 6000 ULN Series Controller. It is connected to the controller's rear panel MANUAL port.

Deflecting the joystick forward or backward operates the Axis 1 motor while moving it side to side operates Axis 2. Actuation of Axis 3 is accomplished by rotating the knob located on the end of the joystick shaft. In all cases the speed of the Inchworm Motor is a function of the amount of deflection (or rotation) of the joystick.

The SPEED switch selects the maximum speed that will be produced when the joystick is fully activated. In the HIGH position the motor speed may be varied continuously from 0 to about 2 mm/sec while in the LOW position motors can be run from 0 to about .016 mm/sec. (These speeds are nominal values for a IW-700 Series Motor).

**NOTE:** Although both switch settings will permit low speed motor operation the LOW setting provides much better joystick resolution and control when operating below 0.16 mm/sec.

When the joystick is in its center position it generates the clock that supports the GO HOME function on the front panel of the controller. The frequency generated is 400-550 KHz which will drive the Inchworm at full speed.

The On/Off switch enables or disables all axes of joystick operation. When it is OFF, the GO HOME clock is no longer supported.

The directional sense of the joystick may be changed such that Inchworm motors move in the 'logical' direction for a particular application. This is accomplished by changing the position of jumpers on the bottom of the joystick's circuit board.

To change the jumpers:

1. Turn off the power to the controller.
2. Remove the Model 7005 cable from the joystick by loosening the capture screws on the connector.
3. Remove the three socket head screws at the base of the joystick and remove the joystick cover assembly from the chassis.
4. The jumpers can be adjusted for each axis as shown in Appendix D.
5. After setting the jumpers, replace the socket head screws and the Model 7005 cable.

### 4.3 Model 6005 Handset

The handset permits operation of a single Inchworm Motor on any controller axis. The active axis is selected with the three-position switch located at the lower left of the handset. The handset is connected to the controller's rear panel MANUAL port using its permanently connected cable.

The speed knob, located at the upper right of the handset, controls the speed when the FORWARD or REVERSE buttons are pushed. With the control fully counterclockwise the motor speed will be 4-40 nm/sec. When the control is rotated fully clockwise the maximum motor speed will be 1-2 mm/sec (nominal). The maximum speed depends on the controller option selected, the specific handset, and the type of Inchworm Motor.

The MODE switch, located next to the FORWARD button provides access to three manual modes of operation:

JOG mode causes the selected Inchworm Motor to run only when the FORWARD or REVERSE button is depressed.

OFF mode disables the handset.

In STEP mode, momentarily depressing the FORWARD and REVERSE button causes the appropriate Inchworm Motor to move the distance selected by the controller's Travel function.

**NOTE: The STEP function is available only on Closed Loop Systems.**

**The handset generates a GO HOME clock which varies with Speed knob position.**

The directional sense of the handset can be changed such that Inchworm Motors move in the 'logical' direction of a particular application. This is accomplished by changing the position jumpers on the bottom of the handset's circuit board. See Appendix D.  
To change the jumpers:

1. Turn off the power to the controller.

2. Remove the four Phillips head screws located on the base of the handset and then remove the case.
3. Change the jumper positions as indicated in Appendix D.
4. Replace the case and secure with the screws.

**NOTE:**      **The STEP function cannot be used with Open Loop Systems.**

**Changing the position of the Mode switch or the Axis Select switch while an Inchworm Motor is operating will abort the operation and stop the Inchworm Motor.**



## 5. INTERFACING

### 5.1 Manual Port Open Loop Interface (6000 ULN)

The Manual Port Open Loop Interface allows open loop control of as many as three Inchworm Motors individually or simultaneously. The following functions are available with this interface: Run/Halt, Forward & Reverse, and Run or Single Step mode. Note that with Single Step mode, the step size is not quantized, however small, as there is no position feedback. The step size is simply the smallest increment of motion of the Inchworm Motor - consult the specific Inchworm Motor manual for further information.

#### 5.1.1 Manual Port Pin Descriptions (Open Loop)

The interface is a 25-pin "D" type connector labeled "MANUAL PORT" located on the rear panel of the controller. In addition to accepting TTL signals for motor control, the interface supplies +5, and +/-12 volts for use in powering external circuits. Two ground lines are also provided.

**NOTE:** The use of an asterisk "\*" on signal lines indicates a logic "Ø".

#### MANUAL PORT Connector Pinout: Open Loop System

| Pin Number | Signal Name             | Input/Output | Signal Type | Signal Level |
|------------|-------------------------|--------------|-------------|--------------|
| 1.         | +5 volts                | O            | Analog      |              |
| 2.         | Ground                  | O            | Analog      |              |
| 3.         | -12 volts               | O            | Analog      |              |
| 4.         | PORT OFF/ON*            | I            | Digital     | TTL          |
| 5.         | -                       |              |             |              |
| 6.         | HALT/RUN* axis 1        | I            | Digital     | TTL          |
| 7.         | CLK1 axis 1 speed       | I            | Digital     | TTL          |
| 8.         | -                       |              |             |              |
| 9.         | HALT/RUN* axis 2        | I            | Digital     | TTL          |
| 10.        | CLK2 axis 2 speed       | I            | Digital     | TTL          |
| 11.        | -                       |              |             |              |
| 12.        | HALT/RUN* axis 3        | I            | Digital     | TTL          |
| 13.        | CLK3 axis 3 speed       | I            | Digital     | TTL          |
| 14.        | +5 volts                | O            | Analog      |              |
| 15.        | Ground                  | O            | Analog      |              |
| 16.        | +12 volts               | O            | Analog      |              |
| 17.        | OPEN LOOP STATUS axis 1 | O            | Digital     | TTL          |
| 18.        | ENABLE* axis 1          | I            | Digital     | TTL          |
| 19.        | FWD/REV* axis 1         | I            | Digital     | TTL          |
| 20.        | OPEN LOOP STATUS axis 2 | O            | Digital     | TTL          |
| 21.        | ENABLE* axis 2          | I            | Digital     | TTL          |
| 22.        | FWD/REV* axis 2         | I            | Digital     | TTL          |
| 23.        | OPEN LOOP STATUS axis 3 | O            | Digital     | TTL          |
| 24.        | ENABLE* axis 3          | I            | Digital     | TTL          |
| 25.        | FWD/REV* axis 3         | I            | Digital     | TTL          |

**NOTE:** See Appendix A for specific electrical TTL Characteristics

### 5.1.2 Manual Port Open Loop Pin Functions

#### Power Supply Pins

##### **+5 VOLT POWER SUPPLY**

The regulated power found on pins 1 and 14 of the interface connector are tied together and can supply the user with +5 volts  $\pm 4\%$  with an absolute maximum current draw of 750 milliamps. Output ripple at 120 Hz will be no more than 800 microvolts. The output is both short circuit and thermally protected. Note that although this supply originates on the High Voltage Driver Board (HVDB), it is separate and distinct from the regulated +5 volts that powers the board.

##### **+12 VOLT POWER SUPPLY**

The regulated supply found on pin 16 of the interface connector supplies the user with +12 volts  $\pm 4\%$  with an absolute maximum current draw of 50 milliamps. The 120 Hz output ripple will be no more than 23 millivolts. The supply regulator is protected from thermal overload and short circuits. This supply also originates on the HVDB but it is separate and distinct from the regulated +12 volt supply that powers the 601 board.

##### **-12 VOLT POWER SUPPLY**

Pin 3 supplies a regulated -12 volts that will not vary more than  $\pm 4\%$  with a maximum current draw of 45 milliamps. The 120 Hz output ripple is less than 4 mv. This supply is also protected from short circuit and thermal overload. This supply originates on the HVDB and is a separate supply from the regulated -12 volts that powers the board.

##### **SUPPLY RETURN LINES**

Pins 2 and 15 are the power supply return lines. They are common with circuit ground of the controller circuitry. In all cases the user must connect his circuit common to these pins in order to properly operate the controller through the interface.

#### CLK1, 2, 3 - Speed Clocks

Separate clock inputs are provided for each axis of the controller which control the Inchworm Motor shaft velocity.

##### **INPUT CLOCK FREQUENCY**

The maximum allowable input frequency is 500 KHz. The nominal frequency in Hertz required for a desired Inchworm shaft velocity in millimeters/second is given by the following equation (for the IW-700 Series motors):

$$Frequency\left(\frac{steps}{sec}\right) = Velocity\left(\frac{mm}{sec}\right) \div \left(2.5\left(\frac{mm}{step}\right) \times 2 \times 10^{-6}\right)$$

Conversely, the nominal motor shaft velocity in millimeters/second for a given input frequency in Hertz is given by the following equation:

$$Velocity\left(\frac{mm}{sec}\right) = Frequency\left(\frac{steps}{sec}\right) \times \left(2.5\left(\frac{mm}{step}\right) \times 2 \times 10^{-6}\right)$$

**NOTE:** IW-700 Series Inchworm Motors are individually factory tested to ensure that they can achieve a minimum speed of 1.5 millimeters per second with a 1.0 Kg load. Maximum speed varies from motor to motor depending on load, motor efficiency, and the stability of the user input clock frequency. Do not rely on the calculated speed if accuracy of speed is a critical factor. Tests should be performed using the actual motors and controller channels that are intended for the final application.

The Inchworm Motor speed will vary over the life of the device along with several other factors. Contact Burleigh for more information.

#### INPUT CLOCK DUTY CYCLE

In order to maintain uniform shaft motion it is necessary that the duty cycle of the input clock be maintained within the boundary of 45% to 55%. The reason is that each transition of the input clock signal, high to low or low to high, produces a clocking pulse to the HVDB circuitry. Thus every clock transition will cause a single staircase step change. If the input clock duty cycle is not approximately 50% the staircase steps derived from input clock transitions will not occur at regular time intervals.

#### FORWARD/REVERSE\* Inputs

When describing the directions of forward and reverse the following convention is used: (for IW-700 Series Motors).

FORWARD: Inchworm Motor shaft extending out of housing.

REVERSE: Inchworm Motor shaft retracting into housing.

The user can change the motion direction of the shaft by changing the state of the FORWARD/REVERSE\* (F/R\*) input line. A F/R\* line is provided for each axis of the 6000. A logic "1" on these pins enable forward motion while a logic "0" enables reverse motion.

#### FORWARD/REVERSE\* INPUT FILTERING

Digital filtering is employed on the HVDB in order to reduce noise on the F/R\* line. The filtering will discriminate between a valid input level and noise pulses up to 500 nS in duration. To be detected the input level desired must be held at that level for at least 500 nS. When a change in state of the F/R\* line occurs, the actual change in Inchworm Motor shaft direction will not occur until at least a 500 nS time period plus the length of time it takes until the next input clock transition (after the 500 nS time period) occurs.

#### HALT/RUN\* Inputs

As the name implies, this line is used to start and stop the Inchworm Motor depending on the state of the line. A logic "0" on these pins enables motion, to the corresponding axis, while a logic "1" stops motion of same.

#### HALT/RUN\* LINE INPUT FILTERING

Digital filtering is employed. The filtering discriminates between valid input levels and noise pulses up to 500 nS in duration. Thus, the HALT/RUN\* line must be at the desired level to be detected. Due to this filtering a delay of about 500 nS plus the time it takes after this 500 nS time period for an input clock transition to take place will occur before a change in the state of the HALT/RUN\* line will take effect.

#### HALT/RUN\* LINE EMULATION VIA CLOCK INPUT

You can use the clock input to emulate the HALT/RUN\* line. With the HALT/RUN\* line to the "RUN" mode one can start and stop the Inchworm Motor by gating the input clock on and off. To run the Inchworm Motor in this fashion the clock will operate as normal. To halt the clock line must be inhibited. This is an alternative method of starting and stopping the Inchworm Motor.

## ENABLE\* Inputs

### ENABLE\* LINE FUNCTION

The ENABLE\* input pins are used to enable or disable an axis from running. A logic "0" on these pins enables the corresponding axis, while a logic "1" disables motion of same.

The ENABLE\* line can be used as an "emergency stop" for each axis or as a global "emergency stop" if all enable lines are tied together. The ENABLE\* lines should not be used as a run/stop line since the ENABLE\* lines have no digital filtering on their inputs as described in the Forward/REVERSE or the HALT/RUN\* sections of 5.D. It is recommended that these lines be hard wired to the "enable" state and remain in that state for normal operation.

## PORT OFF/ON\* Inputs

The Port OFF/ON\* line is an input line that enables and disables the "MANUAL PORT" interface.

### PORT OFF/ON\* FUNCTION

The Port OFF/ON\* line is used to inhibit the entire Open Loop Interface. When in the logic "0" or "low" state, the port is active and will operate as explained in this document. When the Port OFF/ON\* line is in the logic "1" or "high" state the Port is inactive and any activity on the input lines will be ignored. The power supply pins, however, remain unaffected. This input must not be used as an "emergency stop" input. For open loop operation this input must be tied to a logic "0" (port "on") and remain there for proper operation.

## OPEN LOOP STATUS Outputs

The OPEN LOOP STATUS line is an output that in the open loop mode will always be high. No active information is available on this line in the open loop mode.

## 5.2 Manual Port Closed Loop Interface (6200ULN)

The Manual Port Closed Loop Interface provides additional functions and features not available with the Open Loop configuration. This interface provides the same “primitive” control of the Inchworm Motor as the Open Loop interface with the addition of control over the step trigger for Closed Loop systems.

### 5.2.1 Manual Port Pin Descriptions (Closed Loop)

The Manual Port Closed Loop Interface consists only of the 25-pin “D” type connector labeled “MANUAL PORT” located on the rear panel of the controller. This Manual Port accepts TTL signals for motor control, and the interface supplies +5, and +/-12 volts for use in powering external circuits. Two ground lines are also provided.

**NOTE:** For Closed Loop operation, the “MANUAL PORT” pinout is altered from the Open Loop pinout as described below:

**NOTE:** The use of an asterisk “\*” on signal lines indicates a logic “Ø”.

#### MANUAL PORT Connector Pinout: Closed Loop System

| Pin Number | Signal Name              | Input/Output | Signal Type | Signal Level |
|------------|--------------------------|--------------|-------------|--------------|
| 1.         | +5 volts                 | O            | Analog      |              |
| 2.         | Ground                   | O            | Analog      |              |
| 3.         | -12 volts                | O            | Analog      |              |
| 4.         | PORT OFF/ON*             | I            | Digital     | TTL          |
| 5.         | TRIGGER* axis 1          | I            | Digital     | TTL          |
| 6.         | HALT/RUN* axis 1         | I            | Digital     | TTL          |
| 7.         | CLK1 axis 1 speed        | I            | Digital     | TTL          |
| 8.         | TRIGGER* axis 2          | I            | Digital     | TTL          |
| 9.         | HALT/RUN* axis 2         | I            | Digital     | TTL          |
| 10.        | CLK2 axis 2 speed        | I            | Digital     | TTL          |
| 11.        | TRIGGER* axis 3          | I            | Digital     | TTL          |
| 12.        | HALT/RUN* axis 3         | I            | Digital     | TTL          |
| 13.        | CLK3 axis 3 speed        | I            | Digital     | TTL          |
| 14.        | +5 volts                 | O            | Analog      |              |
| 15.        | Ground                   | O            | Analog      |              |
| 16.        | +12 volts                | O            | Analog      |              |
| 17.        | PROCESSOR ACTIVE* axis 1 | O            | Digital     | TTL          |
| 18.        | STEP MODE axis 1         | I            | Digital     | TTL          |
| 19.        | FWD/REV* axis 1          | I            | Digital     | TTL          |
| 20.        | PROCESSOR ACTIVE* axis 2 | O            | Digital     | TTL          |
| 21.        | STEP MODE axis 2         | I            | Digital     | TTL          |
| 22.        | FWD/REV* axis 2          | I            | Digital     | TTL          |
| 23.        | PROCESSOR ACTIVE* axis 3 | O            | Digital     | TTL          |
| 24.        | STEP MODE axis 3         | I            | Digital     | TTL          |
| 25.        | FWD/REV* axis 3          | I            | Digital     | TTL          |

**NOTE:** See Appendix A for specific TTL Characteristics

**NOTE:** It is strongly suggested that you do not start and stop the motor in closed loop operation by setting the HALT/RUN\* line to “run” and gating the clock on and off. Performing this action would start and stop the motor without performing a

**TRIGGER.** This would confuse the processor as to what function is being performed and will result in unpredictable closed loop operation. Also, when an axis is in the closed loop configuration a software "stall test" is continuously performed. By gating the clock off to stop the motor the processor thinks the axis is still in the run mode. However, the axis has stopped due to the clock gated off. After approximately 120 seconds the "stall routine" will display an error when in fact no stall error has occurred.

### 5.2.2 Manual Port Closed Loop Pin Functions

In addition to the functions described in the Open Loop section, Level-1 Closed Loop provides the following functions, or differences, on pins 5,8,11,17,18,20,21,23 and 24 of the Manual Port.

#### PROCESSOR ACTIVE\* Output

The PROCESSOR ACTIVE\* (or PA\*) line is an output signal from the counter board that alerts external circuitry that a processor is present to oversee closed loop operations. There is a PROCESSOR ACTIVE\* line for each axis of the controller.

#### STEP MODE Input

One of the unique functions of the closed loop positioning system is its ability to move preset distances (steps) upon command.

##### STEP INPUT LINE FUNCTION

The STEP input line gives the controller the ability to perform a step function. When the STEP line is true which is a logic "1", the axis will be in the STEP mode of operation. If the STEP line is true and the HALT/RUN\* line is "RUN", the next occurrence of TRIGGER will cause the axis to move to a new position based on the step size loaded into the front panel display in the direction selected by the FORWARD/REVERSE\* line.

When the STEP input line is false (logic "0"), the axis will run or halt according to the HALT/RUN\* line and TRIGGER line. It is not running to a target, merely obeying the HALT/RUN\* line. The only closed loop operation that takes place when the STEP line is false is MAINTENANCE. MAINTENANCE is the function by which the Inchworm will maintain the position where it is halted. MAINTENANCE will also function when the STEP line is true.

**NOTE:** In closed loop mode every change of state of the control input lines must be accompanied by a valid TRIGGER (next section).

#### TRIGGER\* Input

For the processor to oversee closed loop operations it must know the state of the input lines in order to determine the proper course of action. This is accomplished by using the TRIGGER input line.

The TRIGGER line is an edge sensitive input signal that is used to interrupt the processor in order to alert it to the fact that a change has occurred on the Level One closed loop input lines and that it must act upon the new input states.

A TRIGGER signal has no effect on the controller when the PORT OFF/ON\* input line is in the "off" state or when the PROCESSOR ACTIVE \* output line is false (logic "1" of "high"). TRIGGER lines are located on pins 5, 8, and 11 of the interface connector.

Each TRIGGER line connects directly to the processor interrupt input. This interrupt is a "transition-activated" interrupt with the active transition from high to low. The steady state level must be high. For proper detection the timing rules as shown in the figures must be observed.

### TRIGGER INPUT LINE FUNCTION

In order to perform a closed loop function with the Level One closed loop interface the user must first establish the desired levels of the STEP line, the FORWARD/REVERSE\* line, the HALT/RUN\* line and the CLOCK input line. *(Keep in mind that each axis of the controller has these signals along with its own TRIGGER line so different combinations of closed loop and open loop motions can be accomplished with each axis).* Next, the TRIGGER line goes active according to the rules described in the previous section. When the TRIGGER function is detected the processor is interrupted, reads the state of the input lines, and directs the counter hardware to perform the desired function as dictated by the input lines. The input lines can be set to their desired levels in any order as long as they are at the desired level when the TRIGGER line is detected.

### TRIGGER EXAMPLE - RUN FUNCTION

Suppose you want to run an Inchworm in the forward direction in closed loop mode. First, the external hardware must make sure that the PROCESSOR ACTIVE\* line is true. Next, the STEP line is set false (logic "0"), The FORWARD/REVERSE\* LINE is set to "forward" and the HALT/RUN\* line is set to "run". An active edge on the TRIGGER input will initiate the "run" function.

To stop the motor, the HALT/RUN\* line is set to the "halt" state and the TRIGGER line once again receives an active edge to perform the "halt" function. If the motor reaches a limit, all you need to do is change the state of the FORWARD/REVERSE\* line and execute a TRIGGER.

### TRIGGER EXAMPLE - STEP MODE

STEP mode differs from just running a motor using the HALT/RUN\* line in that the Inchworm is searching for a target. This motion is actually a "move relative". The target is based on the position the Inchworm is in and the step size loaded into the axis before the step is executed. The step size is determined by the number that is loaded via the front panel display by the user. When a step is executed, the processor adds the step size to the current shaft position and loads this new number into the target register. This number is the new position the Inchworm will seek. The STEP function is a "move relative" motion type because the motor is moving a predetermined distance relative to the current shaft position.

### STEP MODE SETUP

To place an axis in the step mode, the STEP line must be set to the logic "1" state.

**NOTE:** It is not necessary to set this input to the desired state before pulsing the TRIGGER line. It can be set at the same time as the other control inputs and read when a TRIGGER occurs.

### STEP MODE EXECUTION

When step size is loaded and the STEP line set true, the remaining inputs (FORWARD/REVERSE\*, HALT/RUN\* AND CLOCK) can be set accordingly. Upon

receiving a TRIGGER, the motor will move from its starting position in the direction given by the FORWARD/REVERSE line by a distance given by the step size. If additional TRIGGERS are executed before the motor reaches its original target, additional step sizes will be added to the ultimate target. The direction line determines whether the step size is added to the original target or subtracted from the original target.

#### **HALTING IN THE MIDDLE OF A STEP**

If the motor is executing a step and the HALT/RUN\* line is set to the halt mode and TRIGGERed, the Inchworm Motor will stop and maintain the position it was at when the halt TRIGGER was received. Any additional steps taken will be taken relative to this new maintained position.

#### **HITTING A LIMIT IN STEP MODE**

When a motor reaches a limit it is important to remember that as far as the closed loop hardware is concerned the motor is still running to a target. If during execution of step the motor reaches a limit before reaching its target the motor will stop. However, if additional step triggers occur in the same direction as the limit these steps will be added to the target as if the motor were still running. The motor cannot move because the new target is physically outside its range of motion. In order to move the motor from the limit after this happens you must take the necessary number of steps in the opposite direction until new target is within the range of the motor's physical limits.

### **5.3 Auxiliary Port Closed Loop Interfacing (6200 ULN)**

The Closed Loop Interface provides additional functions and features not available with the Open Loop configuration. The 6200 ULN contains High Voltage Driver PCB(s) and Counter/CPU PCB(s). The Counter/CPU board contains all the hardware drivers/receivers and firmware for the micro-controller to provide the "AUXILIARY" TTL interface. All of the closed loop functions are performed in hardware via the 605 counter/processor board (from now on referred to as the 'counter' board). In addition, the Counter Board may hold a "piggyback" PCB which provides an interface for the .5µm encoder used with the system. Included in this extra hardware is Non Volatile RAM (NVRAM) to store this configuration setup data.

Closed Loop control is provided via the AUXILIARY Port and permits bi-directional data transfers by means of a TTL bus. The bus is capable of multiple axis and multiple chassis control.

In this configuration the Manual port connects to a 6005 Handset, 6003 Joystick, or user supplied signals while the "AUXILIARY" port connects to one of the Model 67X Interfaces described in Section 2.2. It should be noted that the Handset, or Joystick, must be set to the "OFF" position for the Model 67X Interfaces to be active as this disables the PORT ON/OFF\* input.

#### **Closed Loop Functionality**

The Closed Loop Interface provides the following control functions:

- Run forward, run reverse
- Halt
- Run mode/step mode
- Step forward, step reverse
- Load absolute target value
- Load step size

- Read current position
- Read Inchworm Motor and controller status
- Control maintenance mode
- Stall motor test function
- Zero reference and counter clear

### 5.3.1 Auxiliary Port Pin Descriptions

The interface is a DB-25 type connector located on the back panel and marked as Auxiliary Port. All inputs are TTL compatible and are internally bused to all axes. Each axis has a 10K ohm pull up on every input.

As previously mentioned, this TTL compatible port connects to a Model 67X Interface. As an alternative the user may wish to provide this interface him/her self - this, however, is not recommended as it is a pain in the butt.

**NOTE:** The use of an asterisk "\*" on signal lines indicates a logic "Ø".

#### AUXILIARY PORT Connector Pinout: Closed Loop

| Pin Number | Signal Name               | Input/Output | Signal Type | Signal Level |
|------------|---------------------------|--------------|-------------|--------------|
| 1.         | DT1* -dead time axis 1    | O            | Digital     | TTL          |
| 2.         | DT2* -dead time axis 2    | O            | Digital     | TTL          |
| 3.         | DT3* -dead time axis 3    | O            | Digital     | TTL          |
| 4.         | DATA I/O - bit 0          | I/O          | Digital     | TTL          |
| 5.         | DATA I/O - bit 1          | I/O          | Digital     | TTL          |
| 6.         | DATA I/O - bit 2          | I/O          | Digital     | TTL          |
| 7.         | DATA I/O - bit 3          | I/O          | Digital     | TTL          |
| 8.         | DATA I/O - bit 4          | I/O          | Digital     | TTL          |
| 9.         | DATA I/O - bit 5          | I/O          | Digital     | TTL          |
| 10.        | DATA I/O - bit 6          | I/O          | Digital     | TTL          |
| 11.        | DATA I/O - bit 7          | I/O          | Digital     | TTL          |
| 12.        | ACK * - acknowledge       | O            | Digital     | TTL          |
| 13.        | LOGIC GND.                | -            | Digital     |              |
| 14.        | CONTROL Bit 0             | I            | Digital     | TTL          |
| 15.        | CONTROL Bit 1             | I            | Digital     | TTL          |
| 16.        | CONTROL Bit 2             | I            | Digital     | TTL          |
| 17.        | CONTROL Bit 3             | I            | Digital     | TTL          |
| 18.        | CONTROL Bit 4             | I            | Digital     | TTL          |
| 19.        | CONTROL Bit 5             | I            | Digital     | TTL          |
| 20.        | DVSTB* - device strobe    | I            | Digital     | TTL          |
| 21.        | DTSTB* - data strobe      | I            | Digital     | TTL          |
| 22.        | CLK1 - speed clock axis 1 | I            | Digital     | TTL          |
| 23.        | CLK2 - speed clock axis 2 | I            | Digital     | TTL          |
| 24.        | CLK3 - speed clock axis 3 | I            | Digital     | TTL          |
| 25.        | No connection, leave open | I            | Digital     | TTL          |

**NOTE:** See Appendix A for specific TTL Characteristics

### 5.3.2 Auxiliary Port Pin Functions

#### DT1,2,3 - Dead Time Outputs

These are TTL compatible CMOS tri-state outputs, each with a 10K ohm pull-up resistor. The outputs are in the tri-state condition until the axis number is selected by the mini jumps on the Counter/CPU board. The signal that is output from the pins is a real time indication of the dead time interval (clamp change interval) of the motor. A high level indicates no clamp change, while the low level indicates that a clamp change is in process. The duration of the low level is approximately 100 microseconds. The duration of the high level is dependent on the user adjustable speed and maintenance speed.

#### DATA I/O

These pins are bi-directional data input/output signals which are TTL compatible CMOS. These signals are common to all axes and each axis is terminated with a 10K ohm pull-up resistor.

#### ACK\* - acknowledge

This is a TTL compatible CMOS tri-state output and is the only handshake signal on the bus. This signal is bused together on all axes and is capable of driving 15 LSTTL loads including the 10K ohm pull-up resistor on each axis. The output is used to tell the host that the 6000 ULN has responded to the data and is ready to accept additional instructions.

#### CONTROL - bits 0-5

These are TTL compatible CMOS inputs and are bused together between all axes. Each axis input has a 10K ohm pull-up resistor. These signals are used to receive the device code, function code, and motor control data from the host.

#### DVSTB\* - device strobe

This pin is TTL compatible CMOS inputs and is used for all axes. Each axis input has a 10K ohm pull-up resistor. This signal is used to strobe the device address.

#### DTSTB\* - data strobe

This pin is TTL compatible CMOS inputs and is used for all axes. Each axis input has a 10K ohm pull-up resistor. This signal is used to strobe the data into the controller.

#### CLK1,2,3 - speed clocks

These are individual TTL compatible CMOS inputs each with a 10K ohm pull-up resistor. These clock inputs determine the speed at which each motor will run (see Section 5.1.1).

## 5.4 Operation

The 6200 ULN Controller can be used with any host computer that has a TTL digital I/O interface by properly connecting the Auxiliary port to the host. The host can then control up to 3 axes per chassis, or by connecting multiple chassis together the host can control up to 15 axes. For long haul TTL interconnections (greater than 6.5 feet), the 6200 ULN can be connected to the host by means of external differential line drivers/receivers. The software in the host must provide the proper timing signals to establish communication with the 6200 ULN. See the sections on Software Protocol Definitions, Hardware Protocol Definitions, and Pin Descriptions. The 6200 ULN Controller can be used with or without a digital front panel. All of the digital display functions can be accessed through the auxiliary port.

### FRONT PANEL LIMIT DISPLAY

When using the Limit Display front panel the "host PC" can read both the position and the condition of the limits by means of the appropriate function codes. Travel Size can also be downloaded from the host to the controller.

The Counter/CPU PCB has two test points for monitoring MSPEED (maintenance speed) and Dwell time. These are used with an oscilloscope as follows:

In the case of MSPEED the probe is connected to TP1 while adjusting pot RV1 for the required frequency. The resultant MSPEED can be calculated from the following formula (for IW-700 Series Motors):

$$Mspeed\left(\frac{\mu m}{sec}\right) = 2x\left(3.9\frac{\mu m}{cycle} \div \left(\left(1000\frac{steps}{cycle} \div \frac{Frequency\ steps}{sec}\right) + .0002\frac{sec}{cycle}\right)\right)$$

Where the frequency is measured at the test point TP1. The frequency can be adjusted down to zero to permanently turn off the maintenance function, but this is not recommended if using the Level-2 auxiliary port. The proper function code should be used to disable the maintenance function.

The Dwell time can be measured via the signal on testpoint TP2 while adjusting pot RV2 clockwise to increase the dwell time. The pulse is a positive signal and must be enabled with the proper function code to cause the dwell timer to be triggered automatically. Be sure to toggle the dwell test mode off before trying to operate an Inchworm Motor.

### DIGITAL DISPLAY FRONT PANEL

All 6200 ULN controllers have NVRAM (non-volatile RAM) which saves the current units of display when the controller is turned off. In addition, all versions of ROM 2.xx or greater will allow the Units to be changed when in the MSPEED mode.

The digital display will also display four different flashing error messages.

1. **POS Error** will alternately flash with the position data to indicate that the position data may be in error due to EMI or encoder problems. This error message can only be cleared by resetting the counter.
2. **Error 01** will alternately flash with the position data to indicate that the CPU has detected a motor stall condition based on the current stall motor parameters. The drive signals to the motor will also be turned off. This error message will be cleared by starting a new motor operation or clearing the counter.

3. **Error 02** will alternately flash with the position data to indicate that the NVRAM has a low battery condition and the data contained in the RAM may be corrupted. This error condition must be cleared by replacing the NVRAM IC U6.
4. **Code Error** will alternately flash with the position data to indicate that the code ROM has detected a SUMCHECK error. This error condition can only be cleared by replacing the CPU ROM IC U5.

#### 5.4.1 Hardware and Software Protocol Definitions

The Level-2 hardware and software provide many features not available with the Level-1 configuration. These are described below.

#### Hardware Protocol Definitions

##### FUNCTION TABLE

| FUNCTION<br>CODE | DESCRIPTION                                                                                                                                                                                                                                                    |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0                | Execute Motor Operation<br>Reads three motor control lines and performs the operations:<br>1. Halt/Run<br>2. Forward/Reverse<br>3. Step Mode/Run Mode                                                                                                          |
| 1                | Reset Counter<br>Clears the position counter. Loads a "0" into the target register for maintaining the zero position if maintenance is enabled.                                                                                                                |
| 2                | Load Travel Size<br>received must be a 24 bit two's complement binary value.                                                                                                                                                                                   |
| 3                | Load a Target Value<br>Loads the new value into the target register and causes the motor to search for the target position. Data received must be a 24 bit two's complement binary value.                                                                      |
| 4                | Read the Status Byte<br>Returns one to 4 bytes of information where each bit represents a different function such as: forward limit, reverse limit, position error, motor stall error, motor ready, and resolution. The bit values of all bytes are true high. |

The first byte is defined as follows:

|          |                |
|----------|----------------|
| BIT 0    | POSITION ERROR |
| BIT1     | FORWARD LIMIT  |
| BIT2     | REVERSE LIMIT  |
| BIT3     | MOTOR READY    |
| BIT4,5,6 | RESOLUTION     |
| BIT7     | STALL ERROR    |

The second byte contains the following bit information:

|      |                     |
|------|---------------------|
| BIT0 | MANUAL PORT ACTIVE  |
| BIT1 | MAINTENANCE ENABLED |
| BIT2 | TRUE SPEED ENABLED  |

|        |                            |
|--------|----------------------------|
| BIT3   | STALL TEST ACTIVE          |
| BIT4   | DWELL TEST MODE ACTIVE     |
| BIT5   | ZERO REFERENCE MARK ACTIVE |
| BIT6,7 | UNUSED                     |

The third byte contains the following information:

|         |                                  |
|---------|----------------------------------|
| BIT0    | ROM SUMCHECK ERROR STATUS        |
| BIT1    | LOW BATTERY STATUS MVRAM         |
| BIT2    | UNUSED                           |
| BIT3    | DIGITAL DISPLAY UNITS OF IN      |
| BIT4    | DIGITAL DISPLAY UNITS OF MM      |
| BIT5    | DIGITAL DISPLAY UNITS OF $\mu$ M |
| BIT 6,7 | UNUSED                           |

- |   |                                                                                                                                                                                                                                                                                                                      |
|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 5 | Read the Position<br>Returns a three byte value containing both the magnitude and sign of the current position (least to most) with the 24th bit being the sign bit. The data will be in the form of two's complement binary. A fourth byte if read is exactly the same as the first status byte in function code 4. |
| 6 | Enable Zero Reference Mark<br>Enables the zero reference mark on an encoder to reset the position counter and stop the motor.                                                                                                                                                                                        |
| 7 | Extended Function Code<br>Used to generate another function code table.                                                                                                                                                                                                                                              |

#### EXTENDED FUNCTION TABLE

##### # FUNCTION

| EXT CODE | DESCRIPTION                                                                                                                                                                                                                                      |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1      0 | Maintenance Enable (Default)<br>Enables the maintenance mode function. Whenever the motor is at the target position the closed loop control will maintain that position with zero tolerance at the user adjustable maintenance speed.            |
| 1      1 | Maintenance Disable<br>Disables the maintenance mode function. In this mode the controller will NOT maintain the target position.                                                                                                                |
| 1      3 | True Speed Disable (Default)<br>Disables the true speed function. The motor will begin running at a speed determined by the input clock frequency.                                                                                               |
| 1      4 | Set Units Of Display On Front Panel<br>This function is used to set the units of display on the front panel by sending a single byte data value of:<br>1 display units of Inches<br>2 display units of Millimeters<br>3 display units of Microns |
| 1      5 | Reserved                                                                                                                                                                                                                                         |
| 1      6 | Set/Clear Dwell Test                                                                                                                                                                                                                             |

This is a toggle function to set/clear the dwell test mode. When the dwell test mode is active the dwell timer is repetitively triggered to aid in measuring the dwell time on the test point. Normal motor operations are disabled.

|   |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | 7 | Second Extended Function Code<br>Used to generate another function code table.                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 2 | 0 | Stall Motor Test Enabled<br>Enables the stall motor test operation. Whenever the motor is moving the micro controller will test the motion of the motor by determining the position of the motor to a tolerance and time interval. If the motor has not moved more that the specified tolerance and time interval than the motor will be stopped and the stall motor error bit set in the status byte.                                                                                                                            |
| 2 | 1 | Stall Motor Test Disabled (Default)<br>Disables the stall motor test function.                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 2 | 2 | Set Stall Motor Test Parameters<br>This function is used to specify the total time interval and tolerance for the stall motor test function. The first byte is the time interval between each stall test that is performed. The range of this value is 0 to 255 intervals of 10 mS. The second byte is the number of consecutive times that the stall test must be true. The range of this byte is 0 to 255. The third and last byte is the tolerance of the stall motor test. The range of this byte is 0 to 255 encoder counts. |
| 2 | 3 | Returns the Version Number of the ROM                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 2 | 4 | Reserved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2 | 5 | Reserved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2 | 6 | Reserved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2 | 7 | Reserved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

### Software Protocol Definitions

The following is a description of the software protocol necessary to communicate through the auxiliary port from a PC.

#### Level-2 (6200 ULN Controller)

- The binary device address (axis number) must be setup on the lower four control lines (pins 14-17) with the least significant bit on pin 14.
- Next the device strobe (pin 20) is asserted and remains asserted until completion of the data transfer sequence.
- Next the function code (pins 14-16) and the motor control bits (which are required with function code 0 only) are setup on the 6 control lines. Pin 17 is the forward/reverse motor direction line, pin 18 is the motor halt/run line, and pin 19 is the step\_mode/run\_mode control.
- Next the data strobe (pin 21) is asserted and remains asserted until the handshake is received from the 6000 ULN.

- The 6000 ULN Controller processes the data and acknowledges the data transfer by asserting the ACK line (pin 12).
- The data strobe is negated after the acknowledge is received.
- If binary data is transferred to the 6200 ULN then the byte of data is setup on the I/O bus (pins 4-11).
- Next the data strobe is again asserted until the acknowledge is received.
- The data strobe is again negated. This sequence of data setup, assertion of data strobe, acknowledge, and data strobe negation is repeated until all the data is transferred.
- The device strobe can be negated after all the bytes of data have been transferred.
- The sequence of transferring data from the 6200 ULN to the host is similar. The same sequence is used for device address and function code. The 6200 ULN will acknowledge the function code when it is ready to send the data.
- The data strobe is then asserted.
- The 6200 ULN will assert the acknowledged (pin 12) when it has put the data byte on the I/O bus (pins 4-11).
- The host must read the data before negating the data strobe.
- The subsequent data bytes are transferred by using the same sequence as above.
- After all of the data has been transferred the device strobe is negated.



## 6. TROUBLESHOOTING

**CAUTION:** The internal voltages present in the 6000 ULN Series Controller are extremely hazardous. All service operations described in this section are to be performed with the power OFF.

### 6.1 General Troubleshooting

| SYMPTOM                                      | CHECK THE:                                     |
|----------------------------------------------|------------------------------------------------|
| Front panel lights are off                   | Line fuse                                      |
| Inchworm does not make noise                 | HV fuse                                        |
| Inchworm makes noise, but does not move      | HV drive card<br>HV drive card fuse            |
| Position display does not indicate correctly | Resolution jumpers<br>Interface type           |
| Inchworm "runs away" in closed loop system   | Direction jumpers                              |
| Low push force or slow speed                 | Clearance Compensation                         |
| Erratic operation with TTL                   | Not 50% clock signal                           |
| Erratic operations with high mass loads      | Maintenance parameters                         |
| Inchworm moves when joystick is on center    | Joystick zero adjustments<br>(consult factory) |

### 6.2 General High Voltage Circuit Evaluation

The only portion of the 6000 ULN Series Controller circuits that can be serviced easily in the field is the high voltage control section. The parts are usually easily available and the only equipment necessary is a good digital volt-ohm meter which uses low voltage to make its resistance measurements. Beckman, Fluke, Keithley and others make suitable units. It is assumed that the person servicing the instrument is versed in basic electronic troubleshooting techniques. If this is not the case, please consult the factory before proceeding further.

1. If a problem in the high voltage section is suspected remove power from the controller, wait 5 minutes for any stored energy to dissipate, and then remove the instrument cover.
2. The next item to check is the fuse. It should be less than 20 ohms. The value is 63 mA. Never substitute the fuse with any other value. Permanent damage to the controller or Inchworm motor could occur.

3. Locate the high voltage circuit board(s). Locate the high wattage resistors. Check the value of each and replace any which are open or out of tolerance. The values are marked on each resistor. Particularly identify the large "sand" resistors (1K ohm).
4. Finally, check the FET's (lower row of heat sinks). The circuit board will have to be removed from the chassis, so be sure to note where the various connectors are located. Each FET should be checked for resistance from gate to source and gate to drain. Several hundred K ohms should be observed. If any FET shows low resistance is should be replaced with an identical device (BUZ50B).
5. This covers most common problems in the high voltage circuits. If further problems are suspected please contact Burleigh Customer Service Department. They will be able to provide the most current service recommendations, in addition to factory service with OEM parts.

## 7. WARRANTY

Burleigh Model 6000 ULN Series Inchworm Motor Controllers are warranted against defects in material and workmanship for a period of one year after the date of delivery. During the warranty period, Burleigh will repair or, at its option, replace parts which prove to be defective when the instrument is returned prepaid to Burleigh Instruments, Inc. The warranty will not apply if the instrument has been damaged by accident, misuse, or as a result of modification by persons other than Burleigh personnel.

It is important to call Burleigh or your local representative for a RETURN AUTHORIZATION NUMBER (RA#) before returning any product. This will ensure the prompt handling of the repair.

The liability of Burleigh (except as to title) arising out of supplying of said product, or its use, whether under the foregoing warranty, a claim of negligence, or otherwise, shall not in any case exceed the cost of correcting defects in the product as herein, all liability shall terminate. The foregoing shall constitute the sole remedy of the buyer. In no event shall the seller be liable for consequential or special damages.



## APPENDIX A SPECIFICATIONS

### POWER

|                       |                |         |         |
|-----------------------|----------------|---------|---------|
| Line Voltage (R.M.S.) | 90-110         | 107-129 | 180-259 |
| Fuse (Slow Blow Type) | 4A             | 3A      | 3A      |
| Line Frequency        | 50 to 60 Hertz |         |         |
| Power Consumption     | 50 Watts       |         |         |

### VOLTAGES & NOISE PERFORMANCE

|                   |                                        |
|-------------------|----------------------------------------|
| Broadband Noise   | <.005 volts R.M.S.(Clamps & Staircase) |
| Step/Noise Ratio  | >40 dB.                                |
| Clamp Voltages    | -200 to +400 (adjustable)              |
| Staircase Voltage | -200 to +300 (fixed)                   |
| Staircase Steps   | 501 ( $\cong$ 1 volt/step)             |

### OPERATING CONDITIONS

|                       |                                |
|-----------------------|--------------------------------|
| Storage Temp. Range   | 0 to 50 degrees Celsius        |
| Operating Temp. Range | -40 to +70 degrees Celsius     |
| Humidity Range        | 0 to 90% R.H. (non-condensing) |
| Environment           | Normal laboratory              |

### PHYSICAL SIZE

|                               |                                                                                            |
|-------------------------------|--------------------------------------------------------------------------------------------|
| Height                        | 7.2 inches (183 mm)                                                                        |
| Width (w/o rack mount kit)    | 17.4 inches (442 mm)                                                                       |
| Width (w/ rack mount kit)     | 19.0 inches (483 mm)                                                                       |
| Depth (unit only)             | 14.7 inches (374 mm)                                                                       |
| Depth (required, with cables) | 20.7 inches (526 mm)                                                                       |
| Weight                        | 38 pounds (17 Kg)                                                                          |
| Construction                  | Aluminum and steel chassis. Exterior coated with baked enamel finish.                      |
| Maintenance                   | Intake filter to be cleaned when visibly dirty. No other periodic maintenance is required. |
| Reliability                   | 3000 Hrs. MTBF (est.)                                                                      |

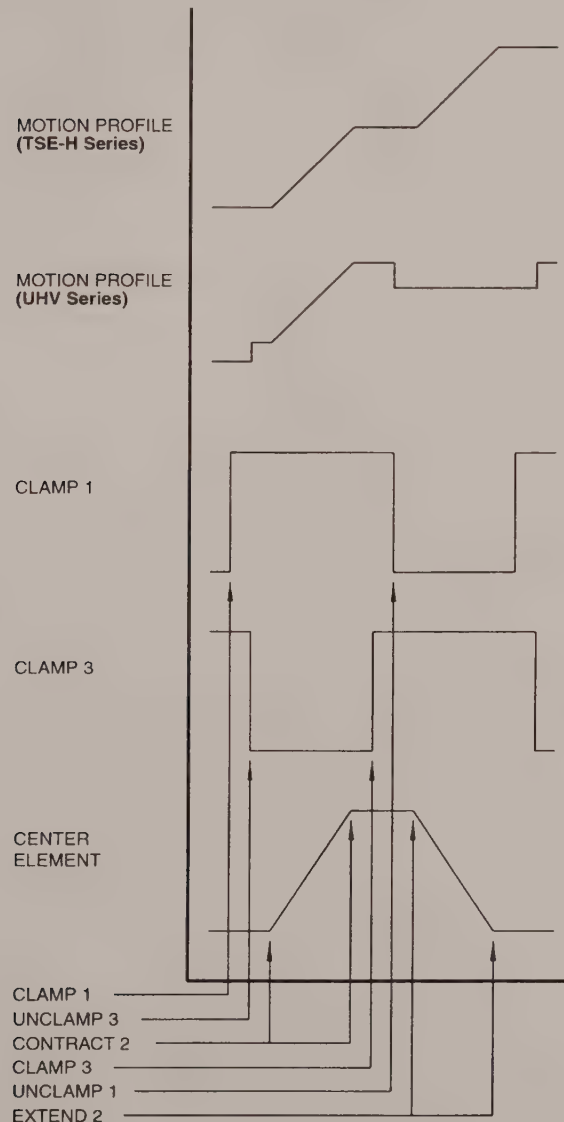
### TTL CHARACTERISTICS

- Minimum high level input = 3.15 V
- Input current @ min high level input = 185  $\mu$ A
- Maximum low level input = 0.9 V
- Input current @ max low level input = -410  $\mu$ A



## APPENDIX B WAVEFORMS

The mechanical motion of the Inchworm is generated by three independent drive voltages. The voltage applied to a clamp element by the controller has two levels - ON (clamped) and OFF (unclamped). The center element receives a positive or negative sloped ramp voltage (staircase) to smoothly move the shaft. The slope of the ramp signal, coordinated with the clamp change frequency, determines translation speed. The drive voltages and approximate motion profiles for the two styles of Inchworm Motors are graphed below.





## APPENDIX C CONNECTOR PINOUTS

### “MANUAL PORT” Connector Pinout: Open Loop System

|                         |                               |
|-------------------------|-------------------------------|
| 1. +5 volts             | 14. +5 volts                  |
| 2. Ground               | 15. Ground                    |
| 3. -12 volts            | 16. +12 volts                 |
| 4. PORT OFF/ON*         | 17. OPEN LOOP STATUS - axis 1 |
| 5. NC – leave open      | 18. ENABLE* - axis 1          |
| 6. HALT/RUN* - axis 1   | 19. FWD/REV* - axis 1         |
| 7. CLK1 - axis 1 speed  | 20. OPEN LOOP STATUS - axis 2 |
| 8. -                    | 21. ENABLE* - axis 2          |
| 9. HALT/RUN* - axis 2   | 22. FWD/REV* - axis 2         |
| 10. CLK2 - axis 2 speed | 23. OPEN LOOP STATUS - axis 3 |
| 11. -                   | 24. ENABLE* - axis 3          |
| 12. HALT/RUN* - axis 3  | 25. FWD/REV* - axis 3         |
| 13. CLK3 - axis 3 speed |                               |

### “MANUAL PORT” Connector Pinout: Closed Loop System

|                         |                                |
|-------------------------|--------------------------------|
| 1. +5 volts             | 14. +5 volts                   |
| 2. Ground               | 15. Ground                     |
| 3. -12 volts            | 16. +12 volts                  |
| 4. PORT OFF/ON*         | 17. PROCESSOR ACTIVE* - axis 1 |
| 5. TRIGGER* - axis 1    | 18. STEP MODE - axis 1         |
| 6. HALT/RUN* - axis 1   | 19. FWD/REV* - axis 1          |
| 7. CLK1 - axis 1 speed  | 20. PROCESSOR ACTIVE* - axis 2 |
| 8. TRIGGER* - axis 2    | 21. STEP MODE - axis 2         |
| 9. HALT/RUN* - axis 2   | 22. FWD/REV* - axis 2          |
| 10. CLK2 - axis 2 speed | 23. PROCESSOR ACTIVE* - axis 3 |
| 11. TRIGGER* - axis 3   | 24. STEP MODE - axis 3         |
| 12. HALT/RUN* - axis 3  | 25. FWD/REV* - axis 3          |
| 13. CLK3 - axis 3 speed |                                |

### “AUXILIARY PORT” Connector Pinout: Closed Loop System

|                            |                               |
|----------------------------|-------------------------------|
| 1. DT1* - dead time axis 1 | 14. CONTROL Bit 0             |
| 2. DT2* - dead time axis 2 | 15. CONTROL Bit 1             |
| 3. DT3* - dead time axis 3 | 16. CONTROL Bit 2             |
| 4. DATA I/O - bit 0        | 17. CONTROL Bit 3             |
| 5. DATA I/O - bit 1        | 18. CONTROL Bit 4             |
| 6. DATA I/O - bit 2        | 19. CONTROL Bit 5             |
| 7. DATA I/O - bit 3        | 20. DVSTB* - device strobe    |
| 8. DATA I/O - bit 4        | 21. DTSTB* - data strobe      |
| 9. DATA I/O - bit 5        | 22. CLK1 - speed clock axis 1 |
| 10. DATA I/O - bit 6       | 23. CLK2 - speed clock axis 2 |
| 11. DATA I/O - bit 7       | 24. CLK3 - speed clock axis 3 |
| 12. ACK * - acknowledge    | 25. NC – leave open           |
| 13. LOGIC GND.             |                               |

**"ENCODER" (DB-9)**

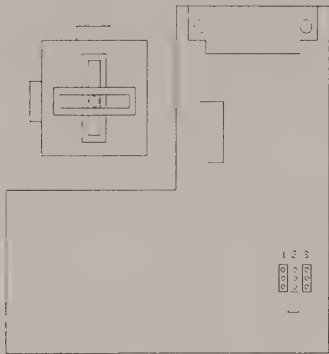
- |                                         |                                       |
|-----------------------------------------|---------------------------------------|
| A. Analog input for .5 $\mu$ m encoders | B. TTL input for .05 $\mu$ m encoders |
| 1. +COS                                 | 1. +12 VOLTS                          |
| 2. -SIN                                 | 2. PHASE 1                            |
| 3. +SIN                                 | 3. ZERO                               |
| 4. Bias Voltage (6v nominal)            | 4. PHASE 2                            |
| 5. N.C.                                 | 5. ZERO*                              |
| 6. SIGNAL GND.                          | 6. PHASE 1*                           |
| 7. +12 VOLTS                            | 7. +5 VOLTS                           |
|                                         | 8. PHASE 2*                           |
|                                         | 9. SIGNAL GND.                        |

**"DEVICE" (DB-9)**

- |                   |                            |
|-------------------|----------------------------|
| 1. FWDLMT*        | 5. CLAMP                   |
| 2. REVLMT*        | 6. N.C.                    |
| 3. STAIRCASE RAMP | 7. EARTH GND - Shield.     |
| 4. CLAMP          | 8. PWR GND - Limit Common. |
|                   | 9. PWR GND - HV Common.    |

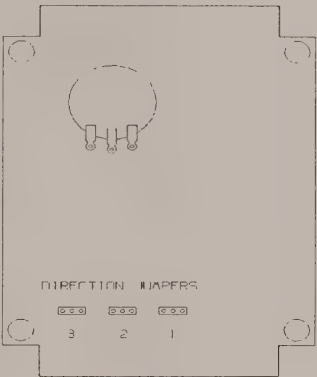
**NOTE:** "\*" indicates TRUE = '0' volts

APPENDIX D HARDWARE CONFIGURATIONS

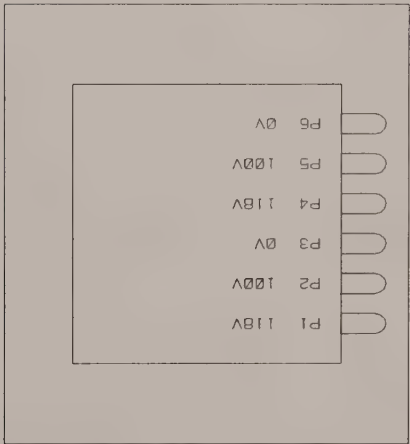


6003 DIRECTION JUMPERS —

6003 Joystick Jumper Locations

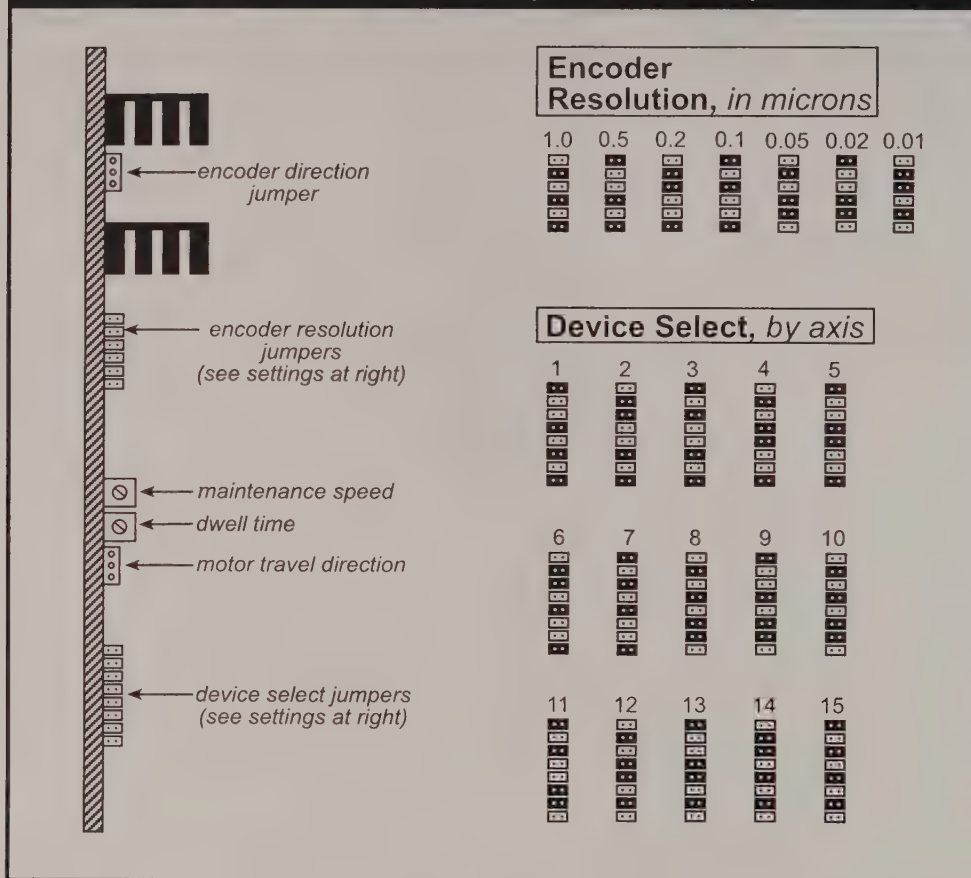


6005 Handset Jumper Locations



6000 Power Transformer Terminal Locations

## Counter/ CPU Card (Model #605)



• indicates jumper position

 indicates empty position

Counter/CPU Card (Model #605)

## INDEX

- Analog Interface, 3-2
- Auxiliary Port
  - Pin Descriptions, 5-10
- Closed Loop, 2-1, 2-3
  - Manual Port, 5-5
- Closed Loop Interface
  - Auxiliary Port, 5-8
- Configuration, 2-1
  - Hardware, D-1
- Connector Pinouts, C-1
- Counter/CPU Card, D-2
- Description, 2-3
- Differential TTL Interface, 3-2
- Digital Display, 5-11
- Display Resolution, 3-3
- DWELL
  - Setting, 4-2
- Encoders
  - Interfacing To, 3-2
- Front Panel, 4-1
- Fuse, 3-3
- Handset, 2-1, 2-3, 3-1, 4-1, 4-4, 5-8
  - Connecting, 3-2
  - Jumper Locations, D-1
- Hardware Configurations, D-1
- Hardware Protocol Definitions, 5-12
- High Voltage Circuit Evaluation, 6-1
- Inchworm Motors
  - Connecting, 3-1
- Initial Test, 3-1
- Installation, 3-1
- Interfacing, 5-1
- Introduction, 1-1
- Joystick, 2-1, 2-3, 3-1, 4-1, 4-3, 5-8, 6-1
  - Connecting, 3-2
  - Jumper Locations, D-1
- Limit Display, 5-11
- Line Voltage Selection, 3-3
- Location, 3-1
- Loop, 4-2
- Maintenance Speed
  - Setting, 4-2
- MSPEED
  - Setting, 4-2
- OEM Module, 2-1
- Open Loop, 2-1, 2-3
  - Interface, 5-1
- Operation, 4-1, 5-11
- Overview, 2-1
- Pin Functions
  - Auxiliary Port, 5-10
  - Auxiliary Port Closed Loop, 5-9
  - Manual Port Closed Loop, 5-6
  - Open Loop
    - Manual Port, 5-2
- Pinouts, C-1
- Power Transformer Terminal Locations, D-1
- Protocol Definitions, 5-12
  - Hardware, 5-12
  - Software, 5-14
- Quality Control, 1-2
- Safety, 1-1
- Single-Ended TTL Interface, 3-3
- Software Protocol Definitions, 5-14
- Specifications, A-1
- Travel
  - Setting, 4-1
- Troubleshooting, 6-1
  - General, 6-1
  - High Voltage Circuit, 6-1
- Warranty, 7-1
- Waveforms, B-1

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